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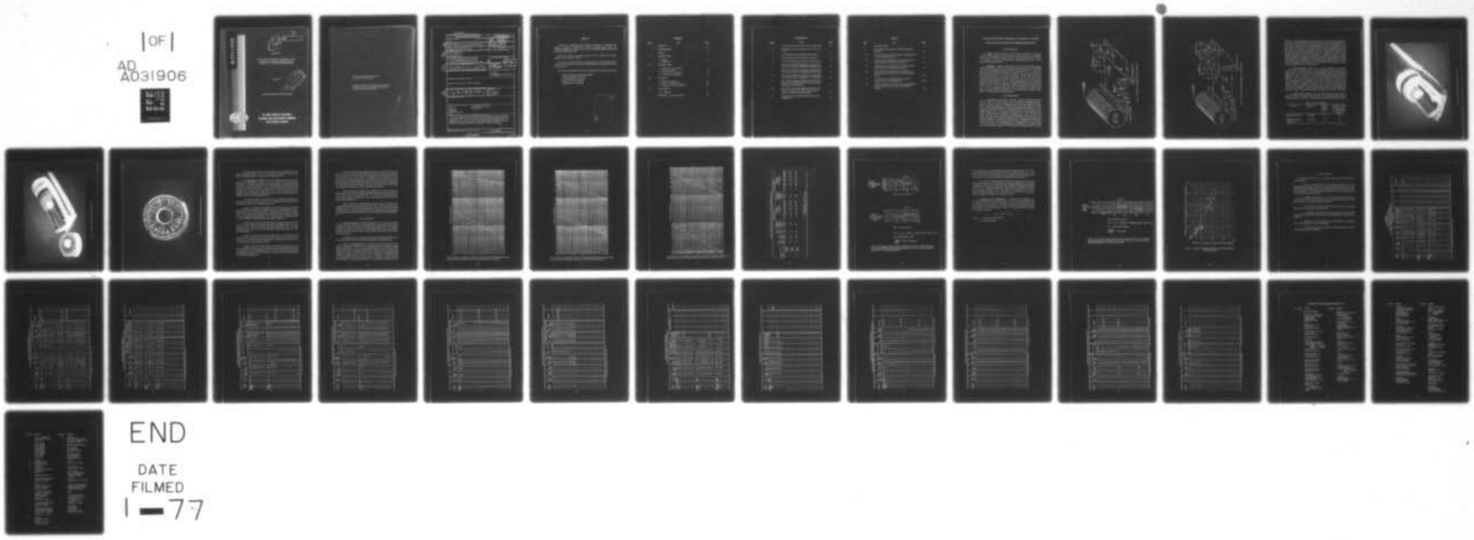

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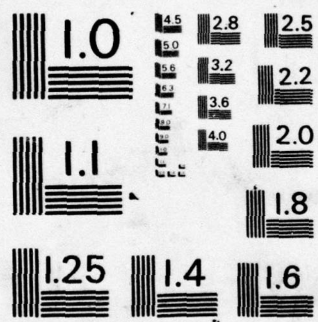

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Report 2176

TEST AND EVALUATION OF COMMERCIAL AND MILITARY STANDARD FILTER/COALESCER ELEMENTS AT LOWERED TEMPERATURES

May 1976

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U.S. ARMY MOBILITY EQUIPMENT
RESEARCH AND DEVELOPMENT COMMAND
FORT BELVOIR, VIRGINIA

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Tests were performed on military standard and commercial filter/coalescer elements to compare their ability to coalesce suspended water from hydrocarbon fuels at temperatures approximately 40 to 65° F. Test fuels were turbine fuel, JP-5, and diesel fuel, No. 2. Comparison tests of two manufacturers of water-in-fuel monitors (turbidimeters) were performed. Charts showing correlations were prepared and formulas were derived.

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PREFACE

Authority for conducting research described in this report is contained in The Catalog of Approved Requirement Documents (CARDS) under Project No. 1G762708D50606 and by request of the US Navy under MIPR N00024-75-MP-5117M (Basic) dated 30 October 1974.

Tests were conducted during January–March 1975 in the POL Test Facility, MERADCOM, Fort Belvoir, Virginia.

The work was conducted under the overall supervision of T. H. Jefferson, Chief, Research and Development Group, Fuels Handling Equipment Division, MERADCOM, Fort Belvoir, Va.

The following MERADCOM personnel participated in the evaluation program:

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Conrad Korzendorfer, Technician
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Lloyd Johnson, Test Mechanic
William Stoney, Test Mechanic

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TEST AND EVALUATION OF COMMERCIAL AND MILITARY STANDARD FILTER/COALESCER ELEMENTS AT LOWERED TEMPERATURES

I. INTRODUCTION

1. **Subject.** This report covers water-removal tests conducted on two types of commercial filter-coalescer elements, Fram and Velcon, conforming to API Bulletin 1581 and on the DOD filter coalescer element conforming to Mil-F-8901. All tests were conducted at below-normal temperatures (approximately 50 to 60° F) with diesel fuel and with turbine fuel.

2. **Background.** Military Standard filter-coalescer elements (DOD) perform satisfactorily for almost all military fuels in temperature levels above 65° F. Mil-F-8901 calls for element qualification in the temperature range of 70 to 90 ± 5° F. Below this level, filter-coalescer element performance is degraded. The US Army is interested in improving the performance of the coalescer elements, especially with diesel fuel, at low temperatures for arctic and marine applications. The US Navy and the West German Navy are interested in removing water from diesel fuel for on-board, turbine-powered hydrofoil watercraft. This is a critical application because of the presence of large amounts of saltwater contaminant. At least two manufacturers have developed coalescer elements to the new API Bulletin 1581 that specifies performance down to 40° F. The two commercial elements, Fram Series 7 and Velcon, and the DOD elements meet the dimensional requirements of Mil-F-52308 and are capable of being fitted to the Military Standard Filter Separators.

II. INVESTIGATION

3. **Description of Test Facilities.** All tests were performed at the MERADCOM POL Test Area. Two closed pumping loops were utilized; a 100-gallon-per-minute (gpm) and a 50-gpm system. The 50-gpm system was used in two different configurations: a single test vessel (Figure 1) and two test vessels in series (Figure 2). In most respects, the test facilities follow those outlined in Mil-F-8901. The basic items in each pumping loop include: a feed tank, a centrifugal pump of suitable capacity, a water-injection system upstream of the pump, a water-flow meter, a test vessel (filter separator), a fuel-flow meter, a turbidimeter for measuring the amount of water in the effluent fuel, gages for measuring temperature and pressure, and suitable piping and valving to operate on a continuing, recirculating basis. A 1000-gallon feed tank located outside is cooled by cold water running over the tank periphery; there are no controls on the cooling system. The centrifugal pump is a Worthington, two-stage pump with two 7¼-inch impellers (50 gpm) or 7½-inch impellers (100 gpm) driven by a 15-hp

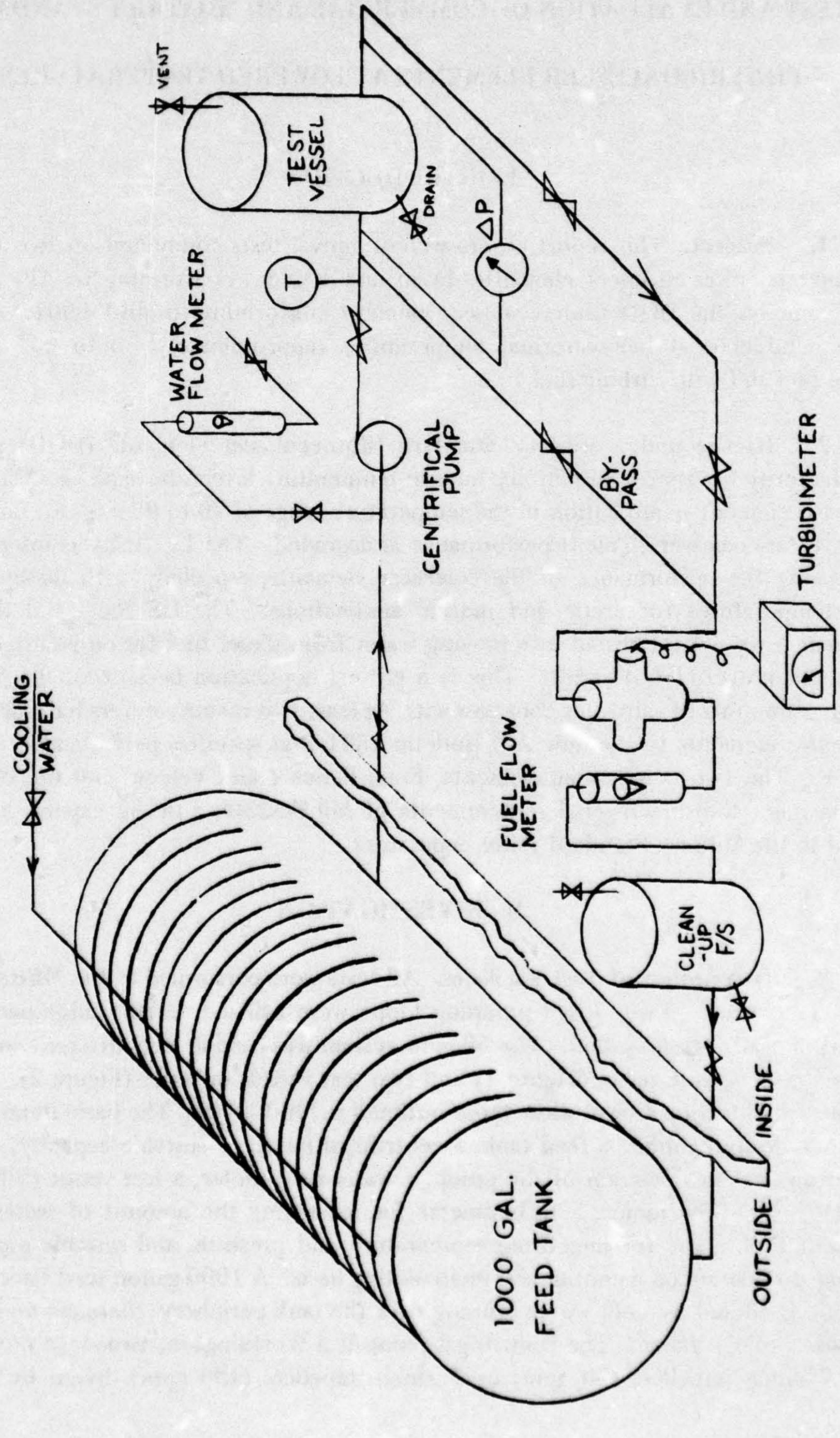


Figure 1. Test facility for low-temperature tests — single vessel.

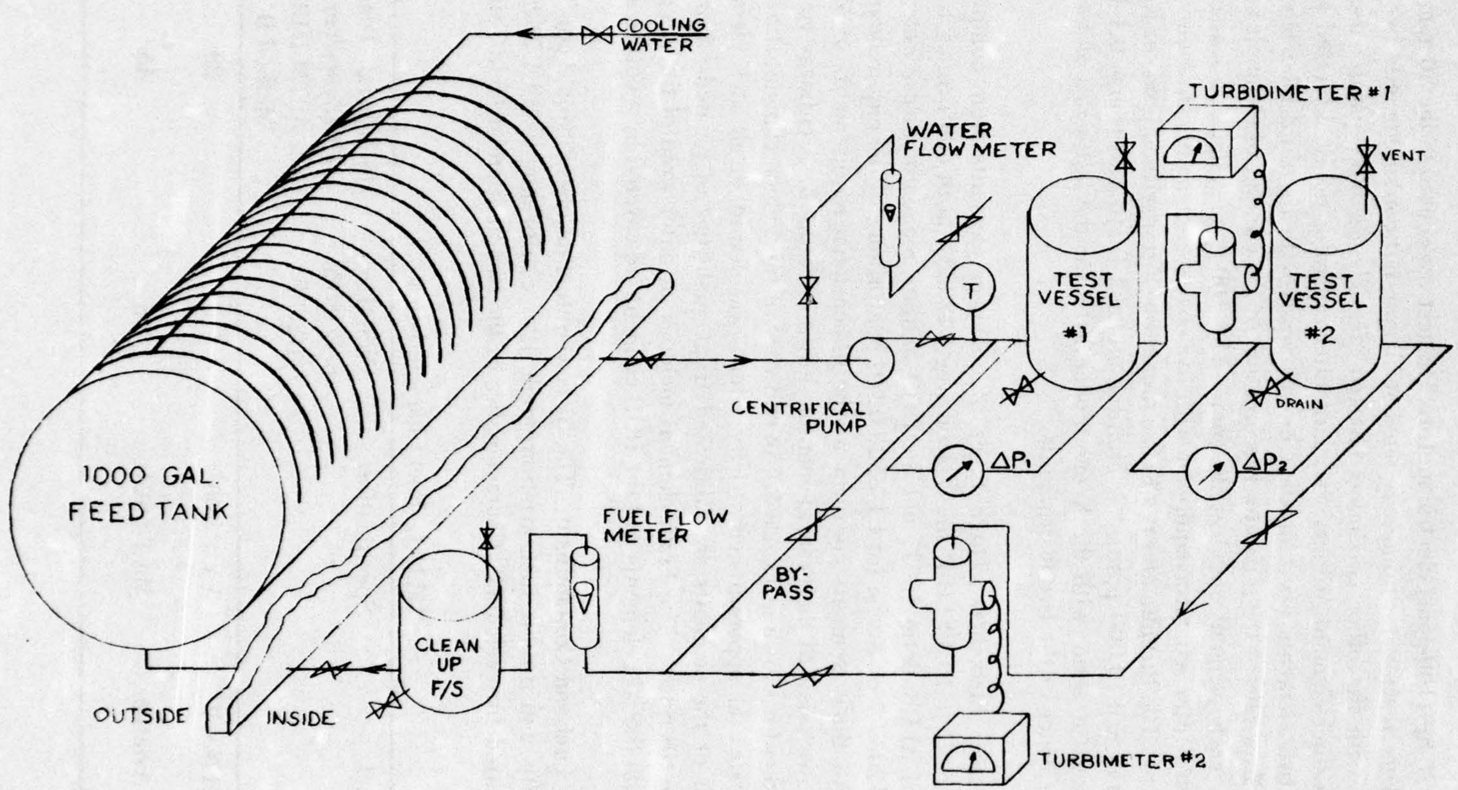


Figure 2. Test facility for low-temperature tests – two vessels in series.

(50-gpm) or a 25-hp (100-gpm) electric motor. The test vessel used in the 50-gpm system is a four-element separator nominally rated at 50 gpm but containing only two test filter elements with the other two inlets blocked off. The second separator used in series tests is a three-element Military Standard filter separator nominally rated at 50 gpm; usually, two elements were installed in this vessel with the third inlet blocked off. The rated flow rate of the separator is a function of the number of elements in the separator with each element rated at 20 gpm. The 100-gpm system uses a single, Military Standard filter separator equipped with five coalescer elements and nominally rated at 100 gpm. The turbidimeter is a Keene model 861F (range 0-30 ppm) or Keene model 861B (range 0-10,000 ppm). A Monitek model LT-210/130 (range 0.1-1000 ppm) was installed in series with the Keene model 861B for the last series of tests to compare performance of the two instruments.

4. **Coalescer Elements.** Three types of coalescer elements were compared: The Fram Series 7 (lot CCS110), the Velcon (log I-42083), both conforming to the requirements of API Bulletin 1581, and the DOD Military Standard coalescer element (Banner lot C12037-7 or Keene lot C1 3520-02-0) conforming to the requirements of Mil-F-8901. All three elements conform to the dimensional requirements of Mil-F-52308. A cutaway view of the Fram element is shown in Figure 3. A cutaway view of the Velcon element is shown in Figure 4. An end view of the Velcon element shown in Figure 5 indicates an apparent eccentricity which was found in all such elements examined. All of the elements are fabricated from quantities of pleated paper and coarse and fine fiberglass. The Fram element includes an outer wrap of fibrous polypropylene. Both the API elements and the DOD element are covered by a cotton sock.

5. ***Test Fuel and Contaminant.*** The fuels were fuel oil, diesel, No. 2, conforming to VV-F-800; and turbine fuel, aviation, grade JP-5, conforming to Mil-T-5624. A single lot was used for each fuel. Characteristics of the two fuels are given in Table 1.

Table 1. Fuel Characteristics

Test Fuel	Specification	WSIM as per ASTM D2550	Interfacial Tension, IFT (dynes/cm) as per ASTM D1331, Method B
Fuel Oil, Diesel No. 2	VV-F-800	13	23
Turbine Fuel, Aviation, Grade JP-5	Mil-T-5624	96	45

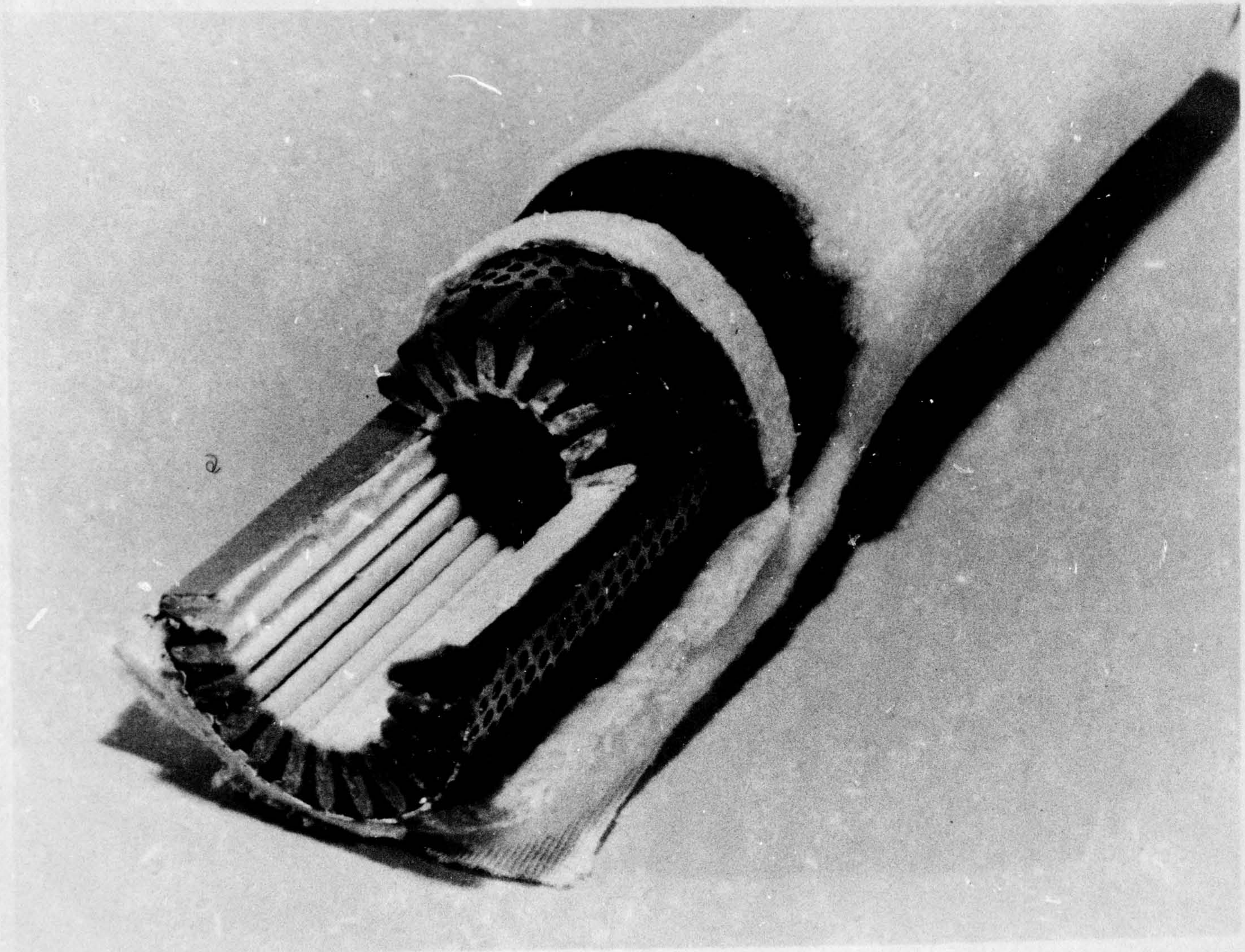


Figure 3. Fram API filter/coalescer element, cutaway view.

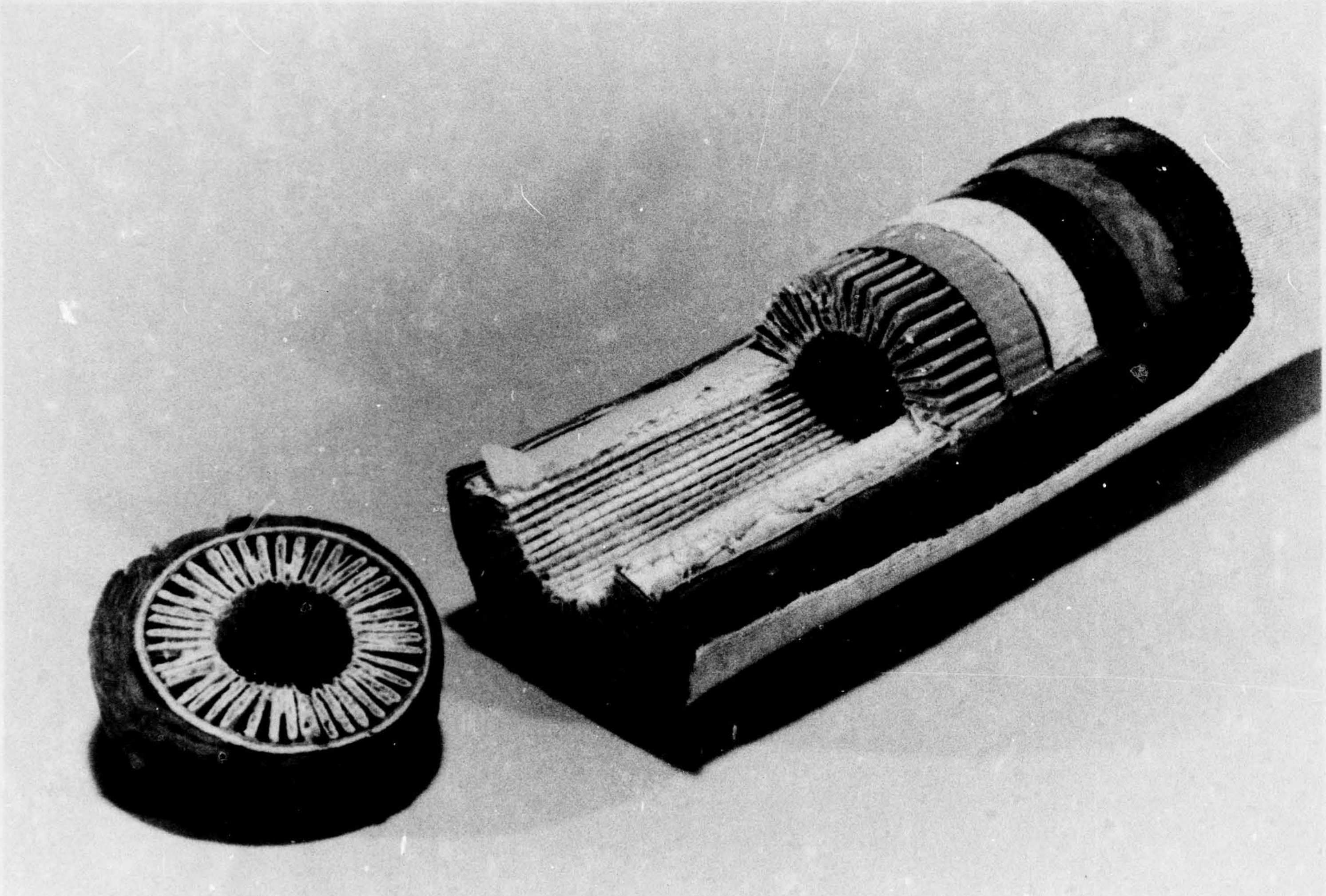


Figure 4. Velcon API filter/coalescer element, cutaway view.

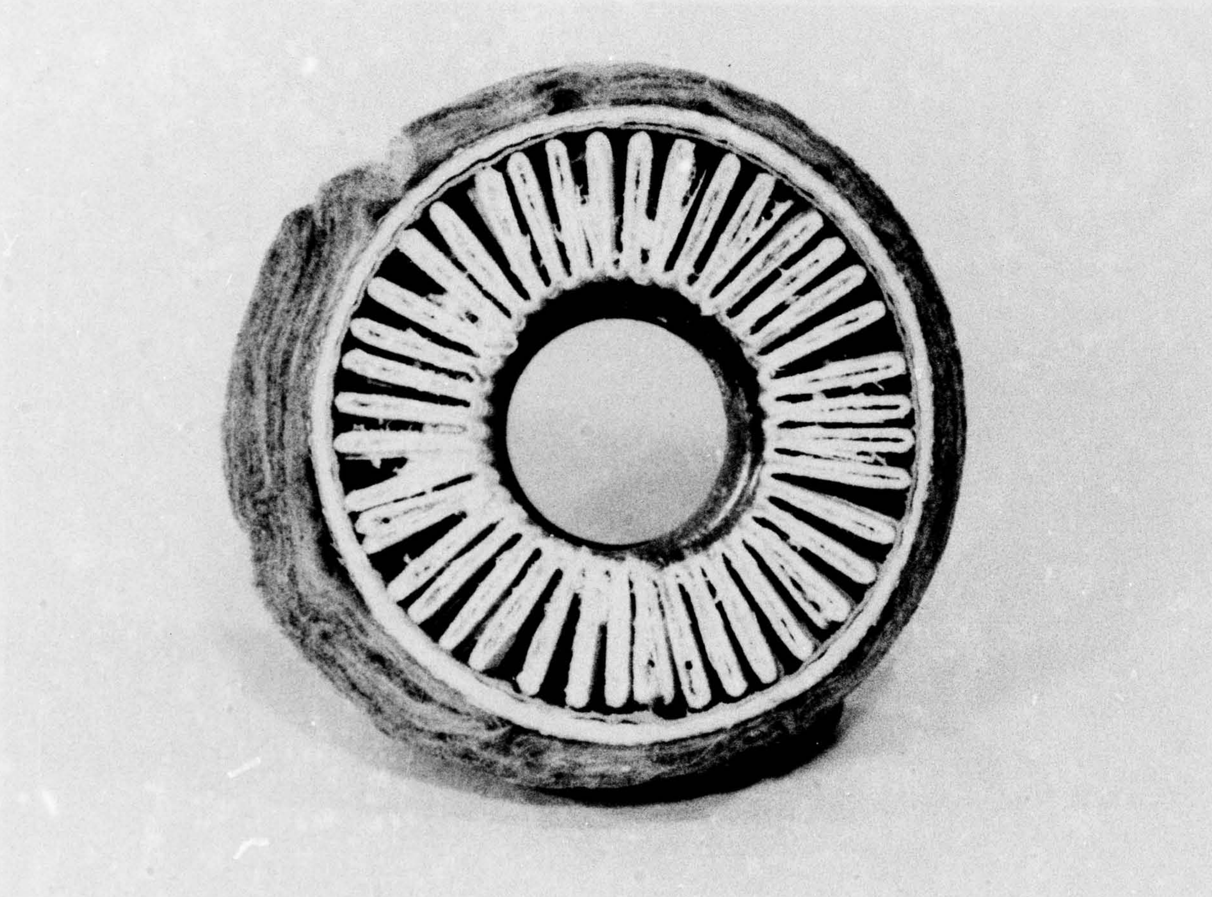


Figure 5. Velcon API filter/coalescer element, end section view.

The water injected into the test fuel during tests was supplied by the Fort Belvoir water utility system. Prior to use, the water was filtered to a residual solids level of 1 milligram per liter. The pH factor varied from 6.5 to 7.0.

6. Test Procedures and Results. Tests were based upon the water-removal tests detailed in Mil-F-8901. A variety of tests was performed to determine optimum flow rate (i.e., the highest possible flow rate while obtaining a reasonably clean effluent) and to compare the performance of the two API filter elements with that of the DOD element. Several conditions were varied: number of filter elements in test vessel, fuel-flow rate, water-add rate, single vessel or two vessels in series operation; the temperature varied according to conditions at the time – only very limited control was possible – but it was usually kept below 60° F.

Tests with diesel fuel were performed first. Fresh batches of diesel fuel were used whenever feasible. Except for the life test, no 1000-gallon, diesel-fuel batch was used for more than 16 hours of testing at any one time.

Results of all testing are summarized in the Appendix, Tables A1 through A6. For reasons of simplicity, the detailed test sheets are not included but each test is summarized as follows: pressure and water in effluent are shown only at test completion or at time indicated; temperatures shown represent the range with the first figure that of test initiation and the last figure that of test completion. Original test sheets are stored in Bldg 362, MERADCOM, and are available for inspection.

Table A1 represents nearly identical diesel fuel tests performed on the Fram, Velcon, and DOD elements with a single vessel with two 20-gpm elements and run at 50% and 25% of rated flow with 0.5% and 2.0% water-injection rates. At similar temperature ranges, the Velcon elements demonstrate superior performance in water-removal efficiency.

Table A2 represents diesel fuel tests performed on the Fram and Velcon elements with two vessels in series and run, for the most part, at 50% and 66.7% of rated flow with 5.0% and 10% water-injection rates. Performances of the Fram and Velcon elements were approximately the same.

Table A3 represents identical diesel fuel tests performed on the Fram, Velcon, and DOD elements with two vessels in series and run at 50% and 25% of rated flow with 0.5% and 2% water-injection rates. The Fram elements demonstrated the lowest pressure drop, but the Velcon element was superior in water-removal tests with the DOD element slightly lower.

Table A4 represents flow optimization and life tests with diesel fuel performed on the Fram, Velcon, and DOD elements with two vessels in series and with 0.5% water-injection rate. After a flow rate is determined that will allow no more than 5 ppm water in the second vessel effluent, a sustained life test is performed to determine the rate of element degradation. Both API elements performed considerably better than the DOD elements; the DOD elements were tested only at 10 gpm while the API elements were run at 30 gpm. The Fram element demonstrated the highest overall water-removal efficiency as well as the lowest pressure drop.

Table A5 represents turbine fuel tests performed on the Fram, Velcon, and DOD elements with a single vessel and run at 100% and 115% of rated flow with 0.5%, 7.0%, 5.0%, and 10.0% water-injection rates. The Fram element demonstrated the lowest pressure drop, but differences in water-removal efficiencies between the three elements are not significant.

Table A6 represents a turbine fuel life test performed on DOD elements with a single, 100-gpm vessel and run at rated-flow rate with most of the test at 0.5% water-injection rate. On the eighth day of testing, tests were run at 5.0%, 7.0%, and 10.0% water-injection rates. Concurrent with the life tests, comparisons were made between the Keene 861B turbidimeter (currently used) and the Monitek LT-210/130 turbidimeter.

III. DISCUSSION

7. **Effect of Temperature.** Graphs of temperature (° F) vs water in the effluent fuel (ppm) for both separators in series (based upon the values of Table A4) are shown in Figures 6, 7, and 8. In each case, water-input rate is held at 0.5%. The fuel-flow rate for the Fram and Velcon elements was set at 30 gpm (50% of rated flow) while the fuel-flow rate for the DOD element was 10 gpm (16.7% of rated flow). Data analyses are shown in Table 2.

Correlation was best with the Fram element, but scattering in all three cases was so marked as to preclude the possibility of establishing a working formula.

8. **Effect of Accumulated Flow.** Diesel fuel tests could not always be reproduced exactly because the diesel fuel was recirculated continuously and thus was being cleaned continuously. It was not economically feasible to use a fresh batch (1000 gallons) for each test. The problem was twofold: while the batch of fuel was being continuously cleaned, the filter elements were continuously accumulating material (including surfactants and gums) from the fuel. To determine if accumulated flow had any appreciable effect, a plot was made of hours running time vs ppm water in the effluent (Figure 9). To eliminate differences due to temperature variations, only those

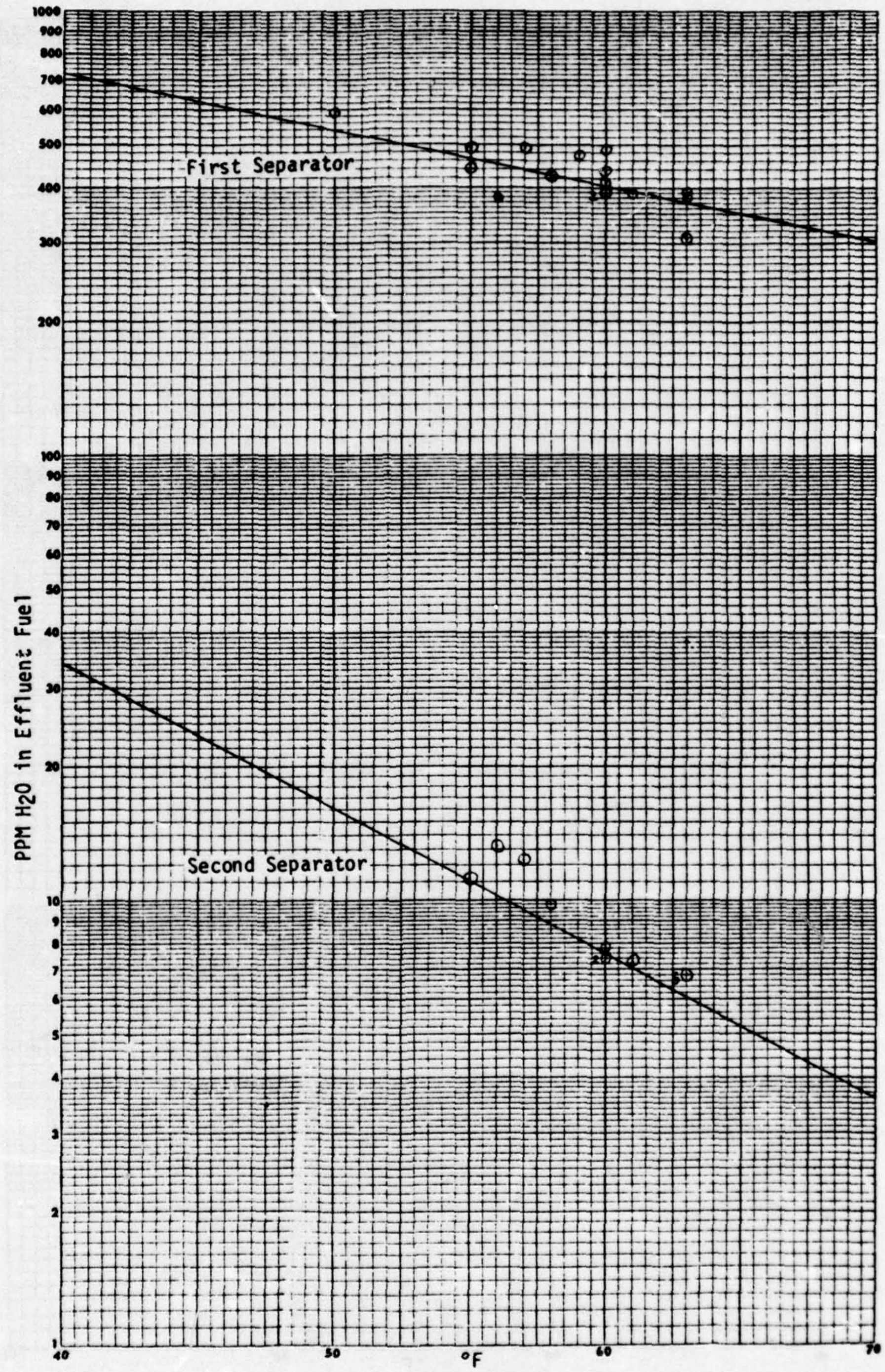


Figure 6. Plot of °F vs log PPM H_2O in effluent with diesel fuel at 30 GPM (50% rated flow) using three, 20-GPM Velcon API elements. (Water input rate = 0.5%) (Data from Table A4)

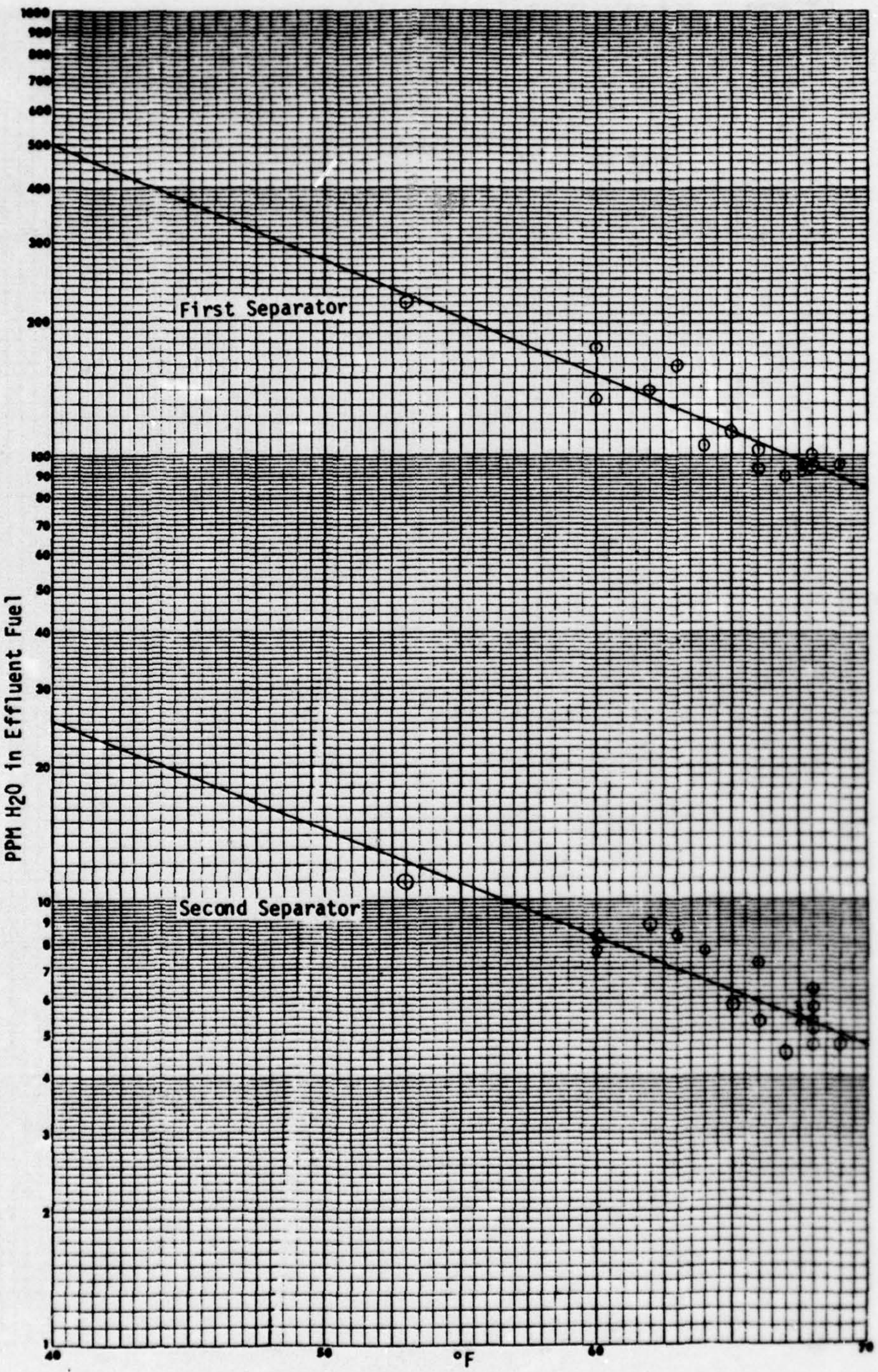


Figure 7. Plot of °F vs log PPM H_2O in effluent with diesel fuel at 10 GPM (16.7% rated flow) using three, 20-GPM Banner DOD elements. (Water input rate = 0.5%) (Data from Table A4)

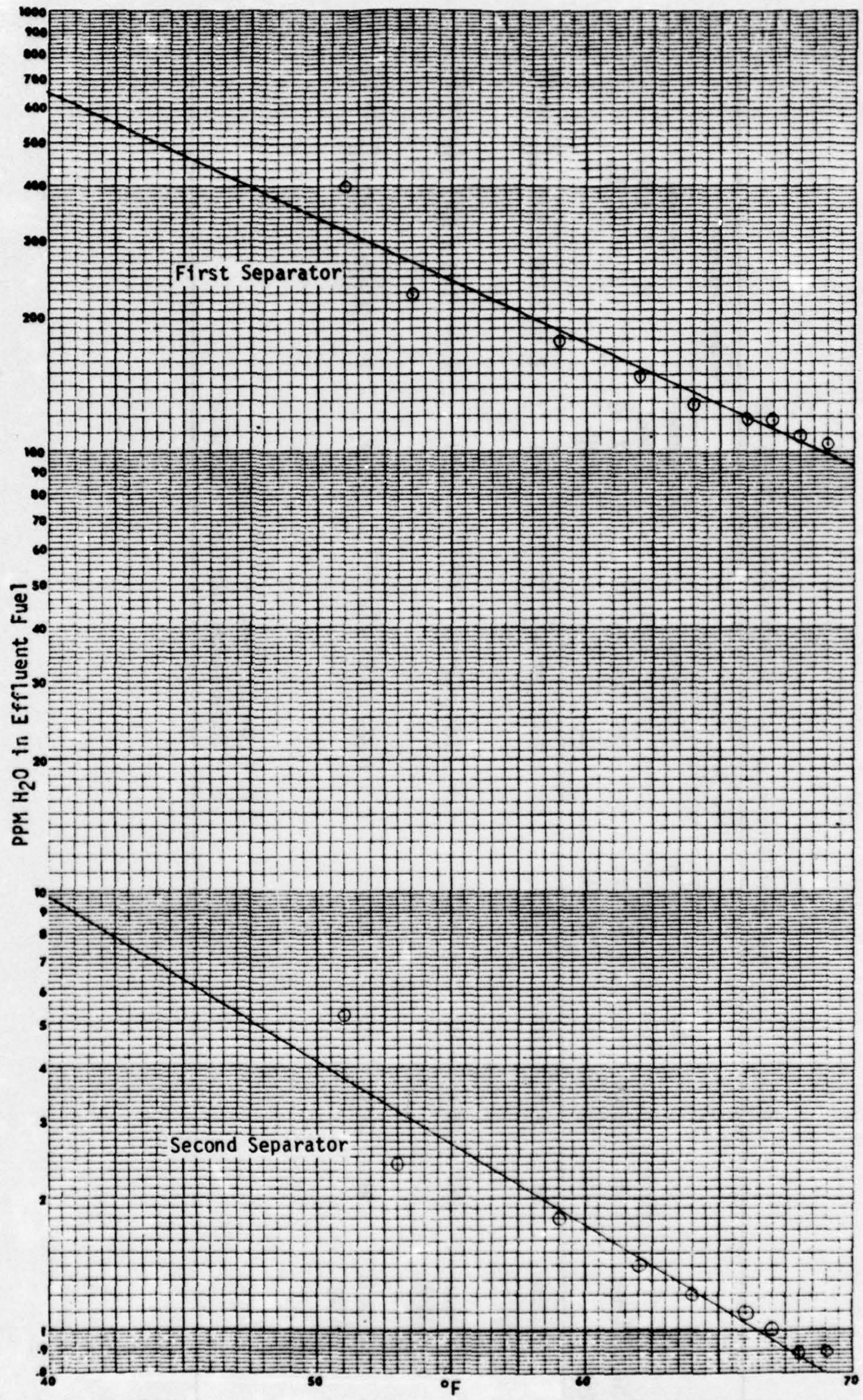
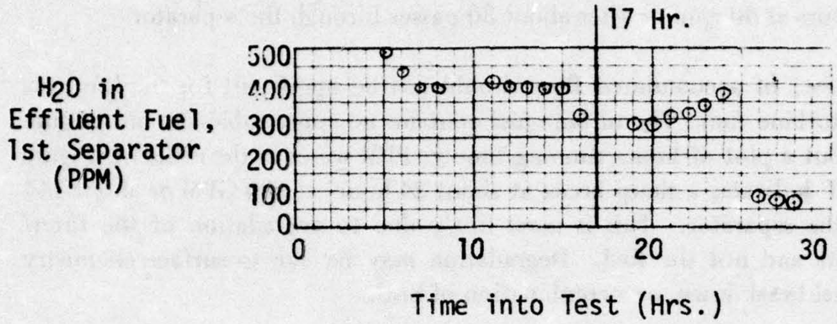


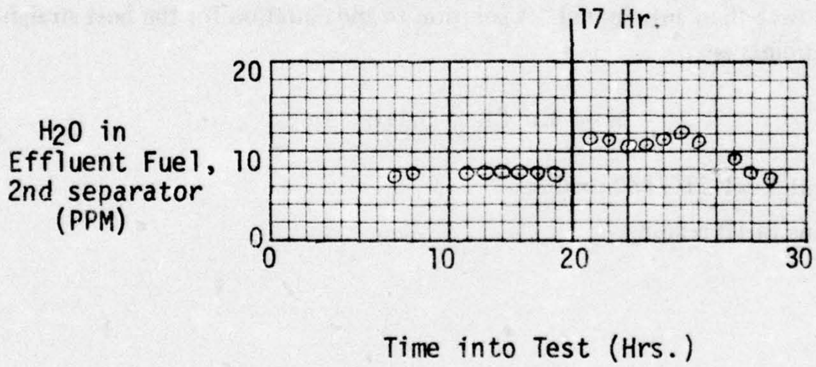
Figure 8. Plot of °F vs log PPM H_2O in effluent with diesel fuel at 30 GPM (50% rated flow) using three, 20-GPM Fram, Series 7, API elements. (Water input rate = 0.5%) (Data from Table A4)

Table 2. Data Analysis of Temperature vs PPM H_2O in Effluent Diesel Fuel

Fig. No. (Graph)	Element	Flow Rate (GPM)	% Rated Flow	H_2O Add Rate (%)	First Separator: Correlation Coefficient log [PPM] vs T (° R)	First Separator: Equation P = PPM H_2O, T = T (° R)	Second Separator: Correlation Coefficient log [PPM] vs T (° R)	Second Separator: Equation P = PPM H_2O, T = T (° R)
6	Banner (DOD)	10	16.7	.05	.783	$P = 8.083 \times 10^{9} \times [e^{-.032T}]$	.761	$P = 2.596 \times 10^{19} \times [e^{-.082T}]$
7	Fram (API)	30	50.0	.05	.927	$P = 2.184 \times 10^{15} \times [e^{-.059T}]$	.923	$P = 3.01 \times 10^{13} \times [e^{-.056T}]$
8	Velcon (API)	30	50.0	.05	.581	$P = 8.519 \times 10^{16} \times [e^{-.065T}]$	.749	$P = 2.096 \times 10^{19} \times [e^{-.084T}]$

° R = Absolute Scale = ° F + 460
e = Natural Logarithm Base = 2.71828





17 hr x 60 x 30 GPM = 30,600 gallons total flow

For a 1000 gallon tank:

$$\frac{30600}{1000} = 30.6 \approx 30 \text{ passes}$$

Figure 9. Plot of time into testing vs PPM H_2O in effluent with diesel fuel at 30 GPM or 50% rated flow using three, 20-GPM Velcon API elements. (Water input rate = 0.5%) Values for temperature range of 62 ± 2° F only. (Data from Table A4)

values obtained over a certain temperature interval were included (62 ± 2° F). Data was obtained from the life test of the Velcon API element (listed in Table A4). As can be seen, the curve remains relatively flat. There appears to be some anomalous values after about 17 hours at 30 gpm or after about 30 passes through the separator.

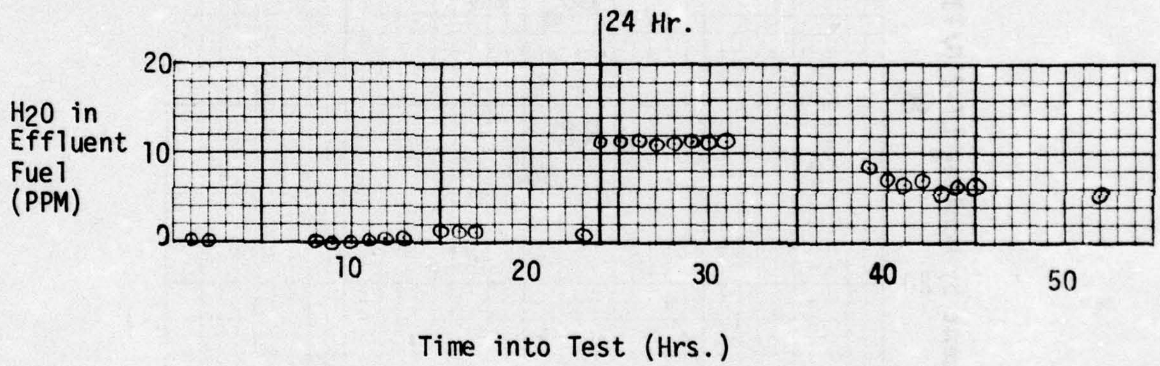
The effect of accumulated flow should not be significant for the life tests performed with turbine fuel. The turbine fuel contains no appreciable amount of gum or surfactants. But a plot of hours running time vs PPM water in the effluent (Figure 10) for 62 ± 2° F indicates a sharp break at about 24 hours at 100 GPM or about 144 passes through the separator. This is most likely due to degradation of the filter/coalescer elements and not the fuel. Degradation may be due to surface chemistry effects, mechanical breakdown, or a combination of both.

9. **Comparison of Two Turbidimeters.** A comparison of the readings of the Keene 861B turbidimeter (range 0-10,000 ppm) and the Monitek LT-210/130 (range 0.1-1000 ppm) was made. A linear relationship was expected, and a linear plot of the two readings is shown in Figure 11. Data analysis indicates a correlation coefficient of 0.873 which is lower than anticipated. A solution to the equation for the best straight line through the points is:

$$M = 1.695K - 3.416$$

Where M = Monitek LT-210/130 reading

K = Keene 861B reading.



24 Hr x 60 x 100 GPM = 144,000 gallons total flow

For a 1000 gallon tank:

$$\frac{144,000}{1000} = 144 \text{ passes}$$

Figure 10. Plot of time into testing vs PPM H_2O in effluent with turbine fuel, JP-5, at 100 GPM or 100% rated flow using five, 20-GPM Keene DOD elements. (Water input rate = 0.5%) Values for temperature range of 62 ± 2° F only. (Data from Table A6)

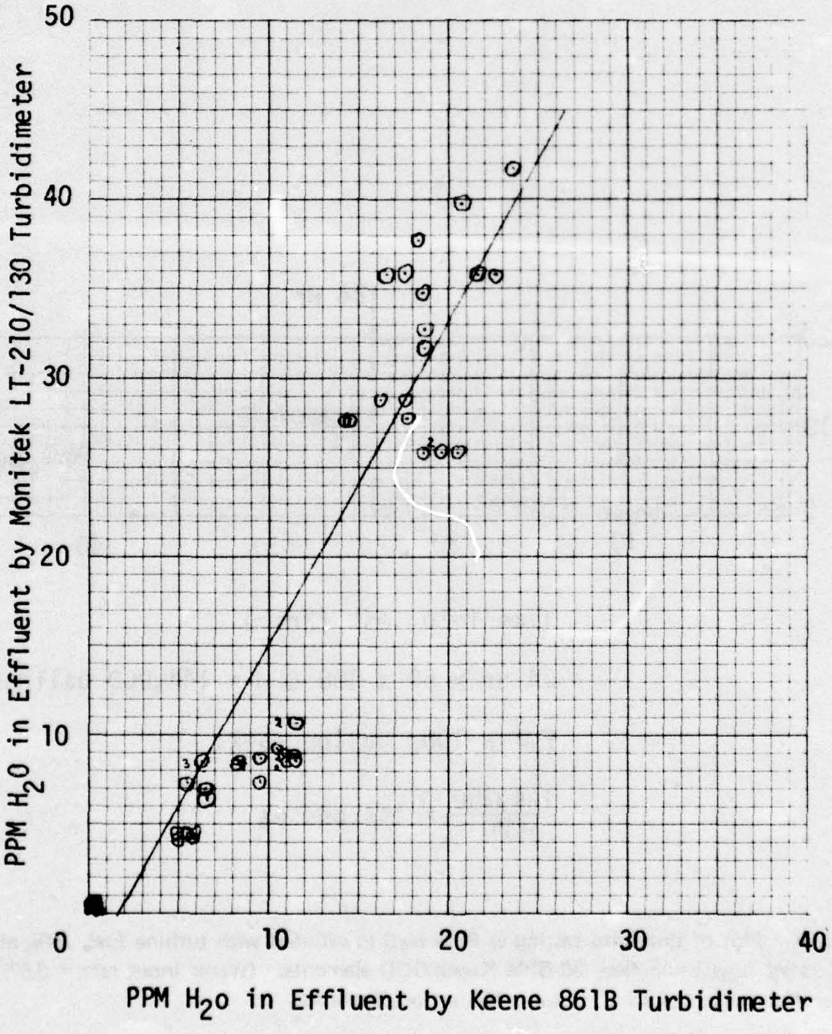


Figure 11. Comparison of Keene 861B and Monitek LT-210/130 Turbidimeters.
(Data from Table A6)

IV. CONCLUSIONS

10. Conclusions. Based upon an examination and analysis of the test data, it is concluded that:

a. The two commercial filter coalescer elements designed to meet API Bulletin 1581 show improved performance over the performance of the Military Standard DOD element in removing water contaminant from diesel fuel at temperatures between 40 and 60° F. The Fram element demonstrates a lower overall pressure drop than the Velcon or the DOD elements.

b. Optimum configuration for a filter separator system for diesel fuel would make use of two filter separators in series using API filter/coalescer elements and with a flow rate no greater than 50% of rated flow.

c. The API elements and the DOD element demonstrate no significant differences in removing water from turbine fuel.

d. A continuously recirculated pumping loop is adequate for filter element testing with diesel fuel if the total number of passes through the test vessel does not exceed 30.

e. Efficiency of water removal is inversely proportional to temperature but no definite formula can, as yet, be established.

f. The Keene 861B and the Monitek LT-210/130 turbidimeters exhibit a moderate amount of linear correlation.

APPENDIX

SUMMARIZED TEST DATA

Table A1. Comparison Tests, Diesel Fuel
Single Test Filter/Separator with Two, 20-GPM Elements

Type of Element	Type of Fuel	Flow Rate (GPM)	% Rated Flow	Fuel Temp. (°F)	H_2O Add Rate (%)	Separator ΔP@ 60 min (PSI)	Separator H_2O Out 10 min (PSI)	Separator H_2O Out @ 60 min (PPM)					Comments
Fram CCSIID	DF-2*	40	100	48-53	0.5	22.0	1295	2795					
(API)	"	40	100	47-54	0.5	18.2	170	210					Retest
	"	20	50	55-59	0.5	10.0	78	95					
	"	20	50	51-55	2.0	11.6	169	179					
	"	10	25	49-55	0.5	5.0	67.5	71.5					
	"	10	25	58-60	2.0	6.0	36.0	53.0					
Velcon I42083	DF-2*	20	50	53-57	0.5	10.0	0.4	17.0					
(API)	"	20	50	47-53	2.0	12.2	83.5	86.5					
	"	10	25	56-61	0.5	6.0	0.7	0.6					
	"	10	25	54-58	2.0	7.0	191	14.6					
Keene CI 3520-02-0	DF-2*	20	50	55-58	0.5	11.3	2.7	126.0					
(DOD)	"	20	50	42-52	2.0	12.3	482.0	377.0					
	"	10	25	60	0.5	7.5	24.0	36.0					
	"	10	25	55-59	2.0	7.2	78.0	76.0					

*Indicates Fresh Batch of Diesel Fuel

Table A2. Comparison Tests, Diesel Fuel
Two Filter/Separators in Series with Three, 20-GPM Elements in Each

Type of Element	Type of Fuel	Flow Rate (GPM)	% Rated Flow	Fuel Temp. (%)	H_2O Add Rate (%)	Time into Test		1st Separator ΔP (PSI)	1st Separator H_2O Out (PPM)	2nd Separator ΔP (PSI)	2nd Separator H_2O Out (PPM)	Comments
Velcon I-42083	DF-2*	30	50.0	44-53	5.0	-	40	16.1	391.3	8.0	3395.6	Test Curtailed
(API)	"	"	"	56-57	5.0	1	-	11.8	60.2	13.0	8.0	Retest
	"	25	41.7	58	5.0	-	40	10.0	42.2	10.0	1.1	
	"	"	"	58	10.0	-	50	10.2	60.2	8.6	1.0	
	"	30	50.0	58-57	10.0	-	40	13.0	92.2	6.0	3.4	
	"	40	66.7	57	10.0	1	-	16.2	122.0	7.0	7.6	
	"	"	"	57-58	5.0	1	-	15.7	76.0	10.0	4.0	
Fram CCSIID	DF-2*	30	50.0	49-53	5.0	1	-	10.0	4033	4.0	75.8	
(API)	"	25	41.7	56-58	5.0	1	-	8.9	3970	6.0	73.3	
	"	20	33.3	55-56	5.0	-	30	7.0	4170	4.0	57.3	Test Curtailed
Fram CCSIID	DF-2*	30	50.0	54-59	5.0	1	-	11.0	177.2	3.0	1.4	Elements Changed
(API)	"	"	"	59	10.0	1	-	11.9	282.2	4.0	1.4	
	"	40	66.7	59-58	10.0	1	-	16.0	287.2	6.0	6.1	
	"	"	"	"	"	2	-	-	252.2	-	7.1	
	"	30	50.0	57-63	5.0	1	-	12.2	200.0	4.0	3.3	
	"	"	"	59-66	"	6	-	11.8	87.0	4.0	1.5	
	"	"	"	46-71	"	7	-	15.1	100.0	6.0	1.5	
	"	30	50.0	42-58	5.0	2	30	16.1	122.0	8.0	2.1	
	"	30	50.0	54-58	10.0	1	-	15.0	106.0	6.0	1.8	

* Indicates Fresh Batch of Diesel Fuel

Table A3. Comparison Tests, Diesel Fuel
Two Filter/Separators in Series with Three, 20-GPM Elements in Each

Type of Element	Type of Fuel	Flow Rate (GPM)	% Rated Flow	Fuel Temp. (°F)	H_2O Add Rate (%)	First Separator: ΔP@ 60 min (PSI)	First Separator: H_2O Out @ 10 min (PPM)	First Separator: H_2O Out @ 60 min (PPM)	Second Separator: ΔP@ 60 min. (PSI)	Second Separator: H_2O Out @ 10 min (PPM)	Second Separator: H_2O Out @ 60 min (PPM)		Comments
Fram CCSIID	DF-2*	20	50	55-60	0.5	5.6	31.8	188.8	2.0	2.0	2.2		
(API)	"	20	50	46-51	2.0	8.0	392.0	452.0	3.0	1.1	3.1		
	"	10	25	63-64	0.5	3.2	62.0	83.0	1.0	0.1	0.1		
	"	10	25	51-56	2.0	4.2	123.0	153.0	0.2	0.4	0.6		
Velcon 142083	DF-2*	20	50	43-49	0.5	10.1	4.6	35.6	3.5	0.2	0.2		
(API)	"	20	50	50-59	2.0	10.8	42.0	58.0	3.0	0.1	0.3		
	"	10	25	51-56	0.5	5.6	1.8	1.8	2.0	0.1	0.2		
	"	10	25	56-59	2.0	6.0	8.8	6.8	2.0	0.1	0.1		
Keene CI 3520-02-0	DF-2*	20	50	43-50	0.5	11.7	6.7	118.7	6.0	0.0	0.0		
(DOD)	"	20	50	52-56	2.0	11.0	240.5	200.5	7.0	0.8	2.6		
	"	10	25	51-56	0.5	6.1	23.6	26.6	3.0	0.1	0.2		
	"	10	25	55-61	20	6.1	70.0	58.0	4.0	0.7	0.3		

*Indicates Fresh Batch of Diesel Fuel

Table A4. Flow Optimization and Life Tests, Diesel Fuel
Two Filter/Separators in Series with Three, 20-GPM Elements in Each

Type of Element	Type of Fuel	Flow Rate (GPM)	% Rated Flow	Fuel Temp. (°F)	H_2O Add Rate (%)	Time into Test		1st Separator		2nd Separator		Comments
						(Hr.)	(Min)	ΔP (PSI)	H_2O Out (PPM)	ΔP (PSI)	H_2O Out (PPM)	
Keene CI 3520-02 (DOD)	DF-2*	60	100	57-59	0.5	-	10	17.0	2132.0	15.0	2142.8	Flow Test
	"	50	83.3	59	0.5	-	10	15.0	2082.0	14.0	1992.8	"
	"	40	66.7	60	0.5	-	10	13.0	1672.0	11.0	1647.8	"
	"	30	50.0	60	0.5	-	10	11.0	982.0	11.0	242.8	"
	"	20	33.3	62	0.5	-	10	9.0	82.0	5.0	13.8	"
	"	10	16.7	64	0.5	-	10	-	7.0	-	0	"
	"	10	16.7	64	0.5	1	-	5.5	3.0	2.0	0	"
Banner CI 2037-3 (DOD)	DF-2	40	66.7	61	0.5	-	10	8.6	1228.0	10.0	1190.0	Flow Test
	"	30	50.0	62	0.5	-	10	7.0	1028.0	5.0	980.0	"
	"	20	33.3	63-64	0.5	-	40	6.0	288.0	6.0	24.0	"
	"	10	16.7	66-67	0.5	1	-	4.0	66.0	2.0	4.6	"
	"	10	16.7	60	0.5	1	-	5.4	135.0	2.0	7.7	Life Test -1st DAY
	"	"	"	62	"	2	-	5.0	140.0	2.0	8.9	"
	"	"	"	64	"	3	-	4.9	105.0	2.0	7.7	"
	"	"	"	66	"	4	-	4.8	95.0	2.0	7.2	"
	"	"	"	68	"	5	-	4.8	100.0	2.0	6.2	"
	"	"	"	68	"	6	-	4.8	95.0	2.0	5.7	"
	"	"	"	68	"	7	-	4.8	95.0	2.0	5.7	"
	"	"	"	69	"	8	-	4.8	95.0	2.0	4.7	"
	"	"	"	55-60	"	9	-	6.5	175.0	3.0	8.3	Life Test-2nd Day
	"	"	"	63	"	10	-	14.1	160.0	3.0	8.3	"
	"	"	"	65	"	11	-	13.4	115.0	2.0	5.8	"

* Indicates Fresh Batch of Diesel Fuel

Table A4. Flow Optimization and Life Tests, Diesel Fuel (cont'd)

Type of Element	Type of Fuel	Flow Rate (GPM)	% Rated Flow	Fuel Temp. (°F)	H_2O Add Rate (%)	Time into Test		1st Separator		2nd Separator		Comments
						(Hr.)	(Min)	ΔP (PSI)	H_2O Out (PPM)	ΔP (PSI)	H_2O Out (PPM)	
	"	"	"	66	"	12	-	13.0	105.0	3.0	5.3	"
	"	"	"	68	"	13	-	12.8	95.0	3.0	5.3	"
	"	"	"	67	"	14	-	12.8	90.0	3.0	4.5	"
	"	"	"	68	"	15	-	12.5	95.0	3.0	5.3	"
	"	"	"	68	"	16	-	12.5	95.0	3.0	5.1	"
↓	"	"	"	53	"	17	-	7.2	221.0	5.0	11.3	Life Test-3rd Day
Fram CCSIID	DF-2*	40	66.7	43-47	0.5	-	30	14.0	585.0	9.0	19.2	Flow Test
(API)	"	30	50.0	49-51	"	-	30	10.8	405.0	7.0	5.2	"
	"	"	"	51	5.0	-	10	12.8	535.0	7.0	13.2	"
	"	"	"	55-63	10.0	1	-	10.1	185.0	7.0	1.1	"
	"	"	"	53	0.5	1	-	10.7	229.0	7.0	2.4	Life Test-1st Day
	"	"	"	59	"	2	-	10.3	179.0	7.0	1.8	"
	"	"	"	62	"	3	-	10.1	149.0	7.0	1.4	"
	"	"	"	64	"	4	-	10.0	129.0	6.5	1.2	"
	"	"	"	66	"	5	-	10.0	119.0	6.0	1.1	"
	"	"	"	67	"	6	-	10.0	119.0	6.0	1.0	"
	"	"	"	68	"	7	-	10.0	109.0	6.0	0.9	"
	"	"	"	69	"	8	-	9.8	104.0	6.0	0.9	"
	"	"	"	55	5.0	1	-	12.0	201.0	6.0	2.3	"
↓	"	"	"	55	10.0	1	-	13.8	111.0	6.0	1.1	"

*Indicates Fresh Batch of Diesel Fuel

Table A4. Flow Optimization and Life Tests, Diesel Fuel (cont'd)

Type of Element	Type of Fuel	Flow Rate GPM	% Rated Flow	Fuel Temp. °F	H_2O Add Rate %	Time into Test (Hr.)	Time into Test (Min)	1st Separator ΔP (PSI)	1st Separator H_2O Out (PPM)	2nd Separator ΔP (PSI)	2nd Separator H_2O Out (PPM)	Comments
Velcon I-42083	DF-2*	40	66.7	40-43	0.5	-	10	18.0	1086.0	7.0	235.4	
	"	30	50.0	45-50	"	-	40	14.5	596.0	7.0	3.8	Life Test-1st Day
	"	"	"	55	"	2	-	13.7	496.0	7.0	4.4	"
	"	"	"	57	"	3	-	13.1	496.0	7.0	12.4	"
	"	"	"	59	"	4	-	12.8	476.0	9.0	—	"
	"	"	"	60	"	5	-	12.8	486.0	9.0	—	"
	"	"	"	60	"	6	-	12.8	436.0	9.0	—	"
	"	"	"	60	"	7	-	13.0	396.0	9.0	7.4	"
	"	"	"	60	"	8	-	13.0	396.0	9.0	7.4	"
	"	"	"	55	"	9	-	13.6	440.0	10.0	11.3	Life Test-2nd Day
	"	"	"	58	"	10	-	13.5	430.0	9.0	9.8	"
	"	"	"	60	"	11	-	13.0	410.0	9.0	7.8	"
	"	"	"	61	"	12	-	12.8	390.0	9.0	7.3	"
	"	"	"	63	"	13	-	12.7	390.0	9.0	6.8	"
	"	"	"	63	"	14	-	12.5	380.0	9.0	6.8	"
	"	"	"	63	"	15	-	12.3	380.0	9.0	6.8	"
	"	"	"	63	"	16	-	12.1	310.0	9.0	6.8	"
	"	"	"	56	"	17	-	13.0	378.0	11.0	13.2	Life Test-3rd Day
	"	"	"	60	"	18	-	13.0	388.0	11.0	11.2	"
	"	"	"	60	"	19	-	13.0	288.0	11.0	10.7	"
	"	"	"	60	"	20	-	13.0	278.0	11.0	10.2	"
	"	"	"	61	"	21	-	13.0	308.0	11.0	10.2	"
	"	"	"	61	"	22	-	13.0	328.0	11.0	11.2	"

* Indicates Fresh Batch of Diesel Fuel

Table A4. Flow Optimization and Life Tests, Diesel Fuel (cont'd)

Type of Element	Type of Fuel	Flow Rate (GPM)	% Rated Flow	Fuel Temp. (°F)	H_2O Add Rate (%)	Time into Test		1st Separator		2nd Separator		Comments
						(Hr.)	(Min)	ΔP (PSI)	H_2O Out (PPM)	ΔP (PSI)	H_2O Out (PPM)	
	"	"	"	60	"	23	-	13.0	358.0	11.0	12.2	"
	"	"	"	60	"	24	-	13.0	378.0	11.0	11.2	"
	"	"	"	57	"	25	-	13.0	110.0	11.0	12.2	Life Test-4th Day
	"	"	"	61	"	26	-	12.8	85.0	11.0	9.7	"
	"	"	"	63	"	27	-	12.5	75.0	11.0	7.8	"
	"	"	"	64	"	28	-	12.5	65.0	11.0	6.7	"
	"	"	"	65	"	29	-	12.0	60.0	11.0	6.2	"
	"	"	"	64-61	5.0	1	-	12.7	2285.0	10.0	18.2	"
	"	*"	"	44-51	10.0	1	-	15.0	3030.0	11.0	33.8	"
	"	"	"	51-53	10.0	1	-	11.0	2180.0	7.0	11.8	"

*Indicates Fresh Batch of Diesel Fuel.

Table A5. Comparison Tests, Turbine Fuel
Single Test Filter/Separator with Two, 20-GPM Elements

Type of Element	Type of Fuel	Flow Rate (GPM)	% Rated Flow	Fuel Temp. (°F)	H_2O Add Rate %	First Separator ΔP @ 60 min (PSI)	First Separator H_2O Out @ 10 min (PPM)	First Separator H_2O Out @ 60 min (PPM)	First Separator H_2O Out > 60 min (PPM)	Second Separator				Comments
Fram CCSIID	Neat JP-5	40	100	44-56	0.5	10.8	0.6	2.2	6.0 (480)					
(API)	"	40	100	54-55	5.0	15.9	6.8	6.8	6.8 (120)					
	"	46	115	46-51	0.5	9.8	0.6	2.0	-					
	"	46	115	45-54	2.0	14.8	8.7	8.7	8.7 (100)					
	"	46	115	54-55	2.0	13.5	4.7	4.7	-					
	"	46	115	54	5.0	17.6	>28.8	>28.8	-					
	"	46	115	54-55	5.0	13.5	4.7	4.7	-					
	"	46	115	51	10.0	15.8	28.8	N/A	-					
Velcon 142083	Neat JP-5	40	100	51-54	0.5	18.0	0	0	-					
(API)	"	40	100	55	2.0	23.8	0.2	0.8	-					
	"	40	100	49-50	5.0	29.5	>30.0	>30.0	-					
	"	40	100	47-50	10.0	30.0	>25.0	>25.0	-					
	"	40	100	46-50	10.0	29.5	26.8	>28.8	-					
	"	46	115	53-56	0.5	14.6	0	0	-					
	"	46	115	55	5.0	26.0	2.0	3.2	3.6 (80)					
	"	46	115	47-50	5.0	26.5	3.3	6.8	-					
Keene CI 3520-02-0	Neat JP-5	46	115	50-53	0.5	14.8	0	0	-					
(DOD)	"	46	115	52	5.0	20.5	1.9	1.9	-					
	"	46	115	52-51	10.0	22.2	8.9	10.9	-					

Table A5. Comparison Tests, Turbine Fuel (cont'd)

Type of Element	Type of Fuel	Flow Rate (GPM)	% Rated Flow	Fuel Temp. (°F)	H_2O Add Rate (%)	ΔP @ 60 min. (PSI)	H_2O Out @10 min (PPM)	H_2O Out @60 min (PPM)	H_2O Out 60 min (PPM)					
Banner CI 2037-3	Neat JP-5	46	115	51-59	0.5	17.0	0.2	0.5	0.8(120)					
(DOD)	"	40	100	51-54	0.5	13.3	0.8	1.3	-					
	"	40	100	59-60	0.5	16.5	0.3	0.4	-					Retest
	"	40	100	53-54	5.0	17.0	9.8	17.8						
	"	40	100	51-54	5.0	23.0	24.7	17.7	>28.7(180)					
	"	40	100	54-52	10.0	20.2	>28.7	>28.7	-					

Table A6. Life Test, Turbine Fuel, DOD Elements
Single 100 GPM Military Standard Filter Separators with Five, 20-GPM DOD Elements

Type of Element	Type of Fuel	Flow Rate (GPM)	% Rated Flow	Fuel Temp. (%)	H_2O Add Rate (%)	Time into Test (Hr.)	Time into Test (Min)	ΔP (PSI)	H_2O Out* (PPM)	H_2O Out** (PPM)	Comments
Keene CI 13530-02	Neat JP-5	100	100	52	0	0	0	6	-	-	First Day
(DOD)	"	"	"	54	0.5	-	10	9	0	-	"
	"	"	"	58	"	-	30	11	0	-	"
	"	"	"	61	"	1	-	14	0	-	"
	"	"	"	63	"	2	-	15	0	-	"
	"	"	"	66	"	3	-	16	0	-	"
	"	"	"	66	"	4	-	16	0	-	"
	"	"	"	69	"	5	-	16	0	-	"
	"	"	"	54	"	6	-	20	0.4	-	Second Day
	"	"	"	58	"	7	-	22	0.4	-	
	"	"	"	60	"	8	-	22	0.1	-	"
	"	"	"	60	"	9	-	22	0.2	-	"
	"	"	"	61	"	10	-	23	0.2	0.34	"
	"	"	"	62	"	11	-	23	0.2	0.18	"
	"	"	"	62	"	12	-	23	0.2	0.18	"
	"	"	"	62	"	13	-	23	0.2	0.44	"
	"	"	"	56	"	14	-	20	0.9	0.15	Third Day
	"	"	"	61	"	15	-	22	0.8	0.01	"
	"	"	"	63	"	16	-	22	0.7	0.43	"
	"	"	"	63	"	17	-	22	0.6	0.35	"
	"	"	"	64	"	18	-	22	0.6	0.35	"
	"	"	"	65	"	19	-	22	0.6	0.38	"
	"	"	"	65	"	20	-	22	0.6	0.37	"

* Using Keene 861B Turbidimeter ** Using Monitek LT-210/130 Turbidimeter

Table A6. Life Test, Turbine Fuel, DOD Elements (cont'd)

Type of Element	Type of Fuel	Flow Rate (GPM)	% Rated Flow	Fuel Temp. (%)	H_2O Add Rate (%)	Time into Test (Hr.)	Time into Test (Min)	ΔP (PSI)	H_2O Out* (PPM)	H_2O Out** (PPM)	Comments		
	"	"	"	65	"	21	-	22	0.6	0.37	"		
	"	"	"	50	"	22	-	24	0.4	0.60	Fourth Day		
	"	"	"	62	"	23	-	24	0.4	0.60	"		
	"	"	"	64	"	24	-	24	11.5	8.60	"		
	"	"	"	63	"	25	-	23	11.5	9.00	"		
	"	"	"	64	"	26	-	23	11.5	9.00	"		
	"	"	"	64	"	27	-	23	11.0	8.40	"		
	"	"	"	64	"	28	-	23	11.0	8.60	"		
	"	"	"	64	"	29	-	23	11.0	9.00	"		
	"	"	"	60	"	30	-	24	11.6	10.80	Fifth Day		
	"	"	"	63	"	31	-	24	11.6	10.80	"		
	"	"	"	65	"	32	-	24	10.6	9.20	"		
	"	"	"	66	"	33	-	23	9.6	8.80	"		
	"	"	"	68	"	34	-	24	9.6	8.80	"		
	"	"	"	69	"	35	-	24	9.6	8.80	"		
	"	"	"	69	"	36	-	24	9.6	8.80	"		
	"	"	"	69	"	37	-	24	9.6	7.30	"		
	"	"	"	56	"	38	-	25	8.3	9.60	Sixth Day		
	"	"	"	60	"	39	-	25	8.2	9.20	"		
	"	"	"	60	"	40	-	25	6.7	6.50	"		
	"	"	"	60	"	41	-	25	6.4	7.00	"		
	"	"	"	60	"	42	-	25	7.2	8.60	"		
	"	"	"	60	"	43	-	25	5.6	7.20	"		

* Using Keene 861B Turbidimeter ** Using Monitek LT-210/130 Turbidimeter

Table A6. Life Test, Turbine Fuel, DOD Elements (cont'd)

Type of Element	Type of Fuel	Flow Rate (GPM)	% Rated Flow	Fuel Temp. (%)	H_2O Add Rate (%)	Time into Test (Hr.)	Time into Test (Min.)	ΔP (PSI)	H_2O Out* (PPM)	H_2O Out** (PPM)	Comments
	"	"	"	62	"	44	-	25	6.2	8.20	"
	"	"	"	62	"	45	-	25	6.2	8.20	"
	"	"	"	54	"	~~45~~ 46	-	23	11.5	8.20	Seventh Day
	"	"	"	55	"	47	-	24	6.0	4.40	"
	"	"	"	56	"	48	-	24	5.0	4.40	"
	"	"	"	57	"	49	-	24	5.8	4.20	"
	"	"	"	58	"	50	-	24	5.5	4.40	"
	"	"	"	58	"	51	-	25	5.0	4.20	"
	"	"	"	60	"	52	-	25	5.5	4.60	"
	"	100	100	55	5.0	-	10	30	20.7	25.80	Eighth Day
	"	"	"	55	"	-	20	30	18.7	25.80	"
	"	"	"	55	"	-	30	30	19.7	25.80	"
	"	"	"	55	"	-	40	30	19.7	25.80	"
	"	"	"	55	"	-	50	30	17.7	27.80	"
	"	"	"	55	"	1	-	30	17.7	28.80	"
	"	"	"	55	"	1	10	30	16.2	28.80	"
	"	"	"	55	"	1	20	30	14.7	27.80	"
	"	"	"	55	"	1	30	30	14.2	27.80	"
	"	100	100	55	7.5	-	10	33	16.7	35.80	"
	"	"	"	54	"	-	20	33	18.2	37.80	"
	"	"	"	55	"	-	30	33	17.7	35.80	"
	"	"	"	54	"	-	40	33	18.7	34.80	"
	"	"	"	56	10.0	-	10	35	22.7	35.80	"

* Using Keene 861B Turbidimeter ** Using Monitek LT-210/130 Turbidimeter

Table A6. Life Test, Turbine Fuel, DOD Elements (cont'd)

Type of Element	Type of Fuel	Flow Rate (GPM)	% Rated Flow	Fuel Temp. (%)	H_2O Add Rate (%)	Time into Test (Hr.)	Time into Test (Min)	ΔP (PSI)	H_2O Out* (PPM)	H_2O Out** (PPM)	Comments		
	"	"	"	54	"	-	20	36	18.7	32.80	"		
	"	"	"	54	"	-	30	36	20.7	39.80	"		
	"	"	"	54	"	-	40	36	23.7	41.80	"		
	"	"	"	53	"	-	50	36	21.7	35.80	"		
	"	"	"	53	"	1	-	37	18.7	32.80	"		

* Using Keene 861B Turbidimeter   ** Using Monitek LT-210/130 Turbidimeter

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